Fischer, Bill.

LAND-USE PATTERNS IN THE TEXAS COASTAL ZONE

Prepared by

BUREAU OF ECONOMIC GEOLOGY

THE UNIVERSITY OF TEXAS AT AUSTIN

Dr. Bill Fischer, Project Leader

Dr. Peter T. Flawn, Director

October 1970

for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

CONTENTS

I. Introduction

II. Specific Use Patterns

A. Agriculture

B. Range-ranchland

C. Woodland-timber

D. Marshlands

E. Urban-industrial-residential

F. Recreation

G. Formal Wildlife Refuges

H. Barren Lands

I. Made Land and Spoil

J. Water

K. Hurricane Flood

L. Shoreline

M. Canals

III. Physical Processes

A. Barriers

B. Tidal Channels

C. Bays and Lagoons

D. Bayhead and Estuarine Deltas

E. Marshes

F. Fluvial Systems

G. Folian Systems

IV. Effects of Man's Activity on Coastal Environments

A. Channelization and Dredging

B. Devegetation

C. Land Reclamation

D. Coastal Construction

E. Waste Disposal

F. Mineral Extraction

LAND-USE PATTERNS, TEXAS COASTAL ZONE

I. INTRODUCTION

The interface of the sea and the land, inherent in a coastal zone, prescribes a variety of land-use patterns. Variations in *relief* (from low coastal marshes and river swamps to upland prairies), in *climate* (from temperate-humid along the upper coast to semi-arid-subtropical in the lower coastal zone), in *soil fertility* (from fertile organic clays to barren sand), and in original *vegetation* (woodlands, prairies, and marshes) are natural features superimposed on the variety of land-use patterns attendant on population and industrial concentration. Further, in the dynamic and diverse environments of the Coastal Zone, the effects of man's use of land and water on natural systems is drawn sharply into focus. The result of these several factors is a complex pattern of land, water, and submerged-land use. Detailed analyses of the several land uses of the Texas Coastal Zone are beyond the scope of this report. Data have been derived from a series of extensive Coastal Zone maps currently in preparation by the Bureau of Economic Geology; at present, these are only partially completed.[1] The categories shown on the accompanying map (Plate I) and the statistical delineation in Table I have been generalized and derived from several of these more detailed maps.[2] Principal general-use categories shown on Plate I include Agriculture (crops), Range-Ranchland (cattle grazing), Woodland-Timber, Marsh (chiefly range and wildlife), Swamp (primarily wildlife), Recreation, Spoil, Made Land, Formal Wildlife Refuges, and No Principal Use Pattern. Industrial, urban, and other cultural features are shown on the Army Map Service topographic base (scale 1:250,000). These features were adapted for use in Table I from detailed maps of the Bureau's Environmental Geologic Atlas Series. Several

---

[1]Anticipated completion date is the late spring of 1971.

[2]Component maps of the Bureau of Economic Geology Environmental Geologic Atlas of the Texas Coastal Zone, currently in preparation, include (1) geologic-landform map, (2) engineering-properties map, (3) topographic map, (4) active physical-properties map, (5) land-use map, (6) mineral and energy resource map, (7) vegetation and animal distribution map, (8) man-made features map, (9) climatic map, and (10) major depositional systems map. An index and map are provided in Attachment A.

categories pertinent to land use and land-use patterns, partially shown on Plate I, are given in the statistical summary of Table I. These include

1. total area: includes both land and water; data for five counties are partial, covering only that portion of the the county shown on the accompanying map:
2. agricultural lands;
3. range-ranchland;
4. woodland-timber areas;
5. marshland-swamp (wetlands) areas;
6. bays (surface-water area);
7. urban-industrial-residential areas;
8. natural fresh-water bodies (surface-water area);
9. artificial reservoirs (surface-water area);
10. recreational lands (primarily public beaches);
11. made lands (reclaimed);
12. formal wildlife refuges;
13. no existing use (principally wildlife);
14. subaerial spoil mounds and spoil wash;
15. hurricane flood areas (areas of inundation by Hurricanes Beulah and Carla);
16. bay-shore line;
17. open ocean-gulf shoreline;
18. total marine shoreline;
19. major drainage and irrigation canals;
20. major transportation canals.

II. SPECIFIC USE PATTERNS

Following are brief notes on the patterns and distribution of principal land and water uses of the Coastal Zone. These cover the 18-county area of the Coastal Zone with the exception of Harris, Jackson, Nueces, San Patirico, and Victoria Counties, which have not been completely surveyed.

AGRICULTURE - Agricultural use of land is extensive within the 18-county area of the Texas Coastal Zone, with approximately *41%* of the total land available in the area used for this purpose: approximately *5,120 square miles are presently under cultivation.* Concentration is on the original prairie grasslands of the central and upper Coastal Zone: agricultural use becomes less extensive in the South Texas Coastal Zone with the progressive decrease in rainfall. Total income from agricultural crops amounted to *$164 million in 1969,* with an additional value of *$25 million in U. S. Government payments*, combined to represent about *10%* of the total State income for these items.

Land is used principally for the cultivation of *rice,* with *60%* of the total production of Texas coming from the Coastal Zone. Main producing counties, north of the San Antonio River, include Brazoria, Chambers, Harris, Jackson, Jefferson, and Matagorda. Relatively high rainfall and extensive irrigation are main contributing factors.

A second important agricultural crop in the Coastal Zone is *grain sorghums,* accounting for about *12%* of the total State production. Principal yields are centered in the Corpus Christi area (Nueces and San Patricio Counties) and in the southernmost part of the Coastal Zone (Willacy and Cameron Counties).

Use of Coastal Zone land in the production of *cotton* is significant only in the Coastal Bend (Calhoun, Nueces, and San Patricio Counties) and in the lower Rio Grande Valley (Willacy County). Approximately *8%* of the total State production comes from the Coastal Zone.

Use of Coastal Zone land for production of *corn* and *hay* is relatively minor, resulting in less than 3% of the total State production. Concentration of these crops is in the central Coastal Zone (Matagorda, Brazoria, and Harris Counties), co-extensive with the area of principal beef production in the Coastal Zone. Grains such as oats and wheat are grown locally, but not in significant quantities.

With the exception of the subtropical lower Rio Grande Valley (Willacy and Cameron Counties), little land of the Coastal Zone is used in the production of *fruits* and *vegetables.* Other areas with at least limited production of these crops usually surround principal population centers.

RANGE-RANCHLAND - Approximately 42% (*4,425 square miles*) of the total area of the Coastal Zone is devoted to range and ranch sites; marshlands also used as range sites include an additional 760 square miles. Principal sites include the more arid region of South Texas, the low-lying coastal marshes, and the nonwooded barrier islands and levees of the central and upper Coastal Zone. The grazing of beef, the production of which accounts for nearly *10%* of the State total, is the principal use of the range land and is most significant in Brazoria, Harris, Jackson, Matagorda, and Victoria Counties. Cash receipts for livestock, mainly beef, from the Coastal Zone amounted to about *$83.5* million in 1969.

WOODLAND-TIMBER - Woodlands occur throughout the Coastal Zone of Texas but are most extensive in Orange County (a southern extension of the East Texas Piney Woodlands), in Brazoria and Matagorda Counties (along existing and ancestral drainage of the Colorado and Brazos Rivers), and in Kenedy County (including vegetated dunes of the South Texas sand sheet). Smaller areas of woodlands elsewhere in the Coastal Zone occur along streams, including low-swamp areas with water-tolerant vegetation, and on certain of the abandoned Pleistocene barrier island sands. Total woodland area in the Coastal Zone is approximately *1,800 square miles* (Table I and Plate I). Principal vegetation in the upper Coastal Zone woodlands includes *pine* and *mixed hardwoods;* in the central Coastal Zone, a variety of *water-tolerant hardwoods;* and in the southern Coastal Zone, chiefly *oak*. Commercial timbering is not significant in the Coastal Zone and is restricted primarily to Orange County. Some natural woodlands have been cleared for agricultural use in the Coastal Zone, but the total acreage for this purpose is small.

MARSHLANDS - Approximately *760 square miles* of the Texas Coastal Zone exist as marshlands or wetlands. These include dominantly low-lying coastal lands, the back sides of barrier islands, and low areas at the terminus of major river valleys and associated bayhead deltas. Salt marshes, brackish marshes, and fresh-water marshes (mapped separately in the Bureau of Economic Geology Environmental Geologic Atlas Series) are restricted to areas below the 4-feet above mean sea level. Grasses of varying tolerance to fresh and salt water are the sole vegetation. Most of the marshlands are used as ranch and range sites for the grazing of beef cattle, although the lowest parts of the marshlands, commonly with salt vegetation, are not overly suited for this prupose. Portions of some of the coastal marshes have been reclaimed, some by filling and others by draining. *Conflicting and detrimental uses of marshlands are considered in another section of this report.*

URBAN-INDUSTRIAL-RESIDENTIAL - General distribution of lands used in this category and their relationship with other uses of the land in the Coastal Zone are shown as a part of the Army Map Service base on the accompanying map (Plate I). Data given in Table I were derived from more detailed base maps. Specific breakdowns in this category are not given at the scale of the accompanying map but have been mapped in the Bureau of Economic Geology Environmental Geologic Atlas Series.

The principal urban and industrial concentration is in the upper part of the Coastal Zone. Highest concentrations are in Brazoria (Freeport area), Jefferson (Galveston area), Harris (Houston area), and Nueces (Corpus Christi area) Counties. Nearly *1,000 square miles* are included in this use category, based on the area covered in the accompanying map. This does not include all such land use in the 18-county Coastal Zone area; for example, only about 20% of the urban-industrial area of Harris County is included in Table I.

RECREATION - The area designated as recreational use, shown on the accompanying map (Plate I) and on Table I, includes primarily public beaches of the Coastal Zone. This amounts to a total area of about 23 square miles. Not included are a variety of public parks and other recreational areas, surface waters, and the National Seashore of Padre Island.

FORMAL WILDLIFE REFUGES - Five major National Wildlife Refuges have been designated in the Texas Coastal Zone: *Anahuac Refuge* in Chambers County (69 square miles); *two refuges* in Brazoria County (a total of 43 square miles); *Aransas Refuge* in Aransas County, with a *small area* extending into Refugio and Calhoun Counties (approximately 83 square miles); and *Laguna Atascosa Refuge* in Cameron County, with a small part extending into Willacy County (approximately 70 square miles). Total area formally designated as wildlife refuge is about *213 square miles*. In addition, wildlife use is coestensive with many of the other use categories.

BARREN LANDS - Barren lands, or land for which there is no existing use other than a limited use for wildlife, comprise nearly *580 square miles* in the Coastal Zone. Principal distribution of these lands is in the semiarid southern part of the Coastal Zone from Kleberg County south. Principally, these include extensive wind-tidal flats landward of Padre Island, as well as some of the active dune fields on the South Texas sand sheet. Smaller areas of wind-tidal flats exist on the back side of barriers in Calhoun and Aransas Counties. A small area of barren land exists in the coastal mudflats of Jefferson County, just south of Sabine Pass.

MADE LAND AND SPOIL - Made land, or land built up to higher levels by grading, represents about 34 square miles in the Coastal Zone. These occur principally in metropolitan areas along the coast: for example, the city of Galveston and most of Pelican Island are both on made land. The areas indicated as subaerial spoil on the accompanying table include only dredged sediment presently above sea level: *the category does not include the extensive areas of subaqueous spoil within the bays. Subaqueous spoil generally flanks dredged canals either as submarine mounds or as reworked spoil flats;* subaerial spoil is most extensive in areas where the Intercoastal Canal is cut into land. Some of the spoil areas have re-established vegetation; other areas are barren.

WATER - The extensive bays of the Coastal Zone comprise the principal surface-water bodies, covering approximately *2,100 square miles* and making up about *13%* of the total surveyed area of the Coastal Zone (Table I and Plate I). Principal bays and estuaries include Sabine Lake; Trinity-Galveston Bay, including East and West Bays; Matagorda Bay, including East Matagorda Bay; Espiritu Santo Bay; Lavaca Bay; San Antonio Bay; Aransas Bay, Copano Bay; Corpus Christi Bay; Baffin Bay; and Laguna Madre. *The bays of the Coastal Zone have extensive uses, many of which are conflicting* - commercial and sport fishing and oystering, recreation, shell dredging, and oil and gas production with their accompanying pipeline systems. Some of the conflicting uses of the bays are considered in another section of this report. Specific features of the mineral industry's uses of the bays are considered in the Task Area on Minerals and Mining.

Fresh-water bodies existing either as natural-water bodies or as artificial reservoirs comprise the other water areas of the Coastal Zone. The surface area of natural-water bodies in the Coastal Zone is about *1,700 square miles;* artificial reservoirs cover about *65 square miles* (Table I and Plate I).

HURRICANE FLOOD - Approximately *3,208 square miles* of the lower parts of the Texas Coastal Zone have been inundated by salt water from surges of Hurricanes Carla and Beulah during the past decade; particularly prone to flooding are the low coastal marshes and the lower reaches of the main river valleys. Coastal flood areas are not specified on the accompanying map (Plate I); statistical data reported in Table I are based on detailed maps of hurricane flooding prepared as a part of the Bureau of Economic Geology Environmental Geologic Atlas Series (available in the spring of 1971).

SHORELINE - Total shoreline in the Texas Coastal Zone amounts to slightly over *1,890 miles*. Of this total, *1,419 miles are bay shoreline* and *373 miles are open-ocean or gulf shoreline*. These figures are computed from detailed 715-minute topographic maps of the Coastal Zone, most of which were constructed during the past decade. The shoreline is a dynamic zone subject to constant change in the form of erosion or accretion: it is thus subject to change in total length. The main physical processes of the shoreline are considered in another section of this report.

CANALS - An extensive canal system has developed in the Texas Coastal Zone, including both *transportation canals* and *irrigation-drainage canals*. Major transportation canals amount to a total of *668 miles* within the surveyed part of the Coastal Zone (Plate I and Table I); this figure includes the portions of the transportation canals dredged within bays, as well as the land-cut parts of the canals. Approximately *3,120 miles of irrigation and drainage* canals have been cut in the Coastal Zone, mostly coestensive with agricultural lands.

III. PHYSICAL PROCESSES

Determining factors in land use are the degree, variety, and nature of physical processes. In the dynamic environments of the Coastal Zone, these factors assume prime importance. A distinct suite of processes affect the barrier islands, the bays, lagoons, and estuaries, and the mainland. Among the more important processes are those that *determine rates of erosion or accretion by either water or wind, extent and kind of flooding, and transportation and dispersal of sediments.* Following is a brief outline of the main physical processes existing in the Texas Coastal Zone, listed in terms of natural systems and their component environments.

A. *BARRIERS*

1. *Shoreface* (offshore, 0 to approximately 30 feet)
   a. *Normal sea conditions* - Onshore and lateral transport of sand by *bottom currents* (tidal and wind-generated waves). Some suspension material deposited on the lower shoreface and mixed with sand through organic activity.
   b. *Storm conditions* - Sand and shell are transported onshore as *large* sand waves. Sand and mud are carried offshore in suspension by turbidity currents and are deposited on parts of the shoreface.

2. *Foreshore and backshore*
   a. *Normal sea conditions* - Sand is spread in thin sheets on the foreshore by swash and backwash; some of this sand is transported by wind across the berm onto the backshore where it may accumulate as coppus mounds. Some areas of the backshore are deflated of sand, leaving a pavement of shell and shell debris.
   b. *Storm conditions* - Under storm conditions the foreshore is eroded and sand is deposited as a storm beach above normal high-tide mark. The beach is reworked by eolian processes.

3. *Foredune ridges*
   These ridges accrete under prevailing southeast-wind conditions; sand is derived from the backbeach area. Hurricane tracks passing over the barrier severely erode the foredunes. Vegetation is the main agent of dune stabilization; this may be severely affected by overgrazing. Salt-tolerant plants are the main stabilizers; therefore, exceptionally heavy rainfall may reduce the plant cover, resulting in dune activation.

4. *Beach-accretion ridges*
   These are affected by the same processes that operate on foredunes.

5. *Storm channels and washover fans*
   Channels are scoured during storms; sand is transported by unidirectional currents toward the bay during storm-surge flood. Sand deposition occurs within the channels as bars and sheets that spread radially away from the distal parts of the channel. These bars form a coalescing sand body called a "washover fan." Some sediment returns seaward through storm channels during the ebb surge. Under normal sea conditions, the seaward part of the channel is sealed with sand that is swept along shore and into the channel mouth by longshore drift; this sediment is then transported bayward with the next storm. Once established, storm channels are avenues of high-velocity storm currents.

6. *Blowouts and dunes*
   Foredune ridges and beach accretion ridges, when barren of vegetation, are eroded by the wind. Sections of foredunes or beach-accretion ridges may be breached when vegetation is removed by fires, overgrazing, etc.. Intense local scour by the wind is termed a "blowout." Downwind from blowouts sand migrates as dunes; dunes will continue to migrate downwind until stabilized by vegetation or until they meet with a body of water. Likewise, blowouts will remain active until the breach is vegetated.

7. *Vegetated barrier flats*
   Sediment accumulation here is chiefly fine sand blown into the area from beach and foredune areas by the prevailing southeast wind. Biologic activity here consists of root-mottling and burrowing by rodents and crustaceans.

8. *Wind-tidal flats*
   Wide, barren areas lying between the vegetated barrier flats and the coastal bays receive much of their sediment from the bay. Generally during periods of strong north wind, these flats are inundated and fine sand is moved across the flats by wind-generated currents. Suspension material settles across the flats as the water recedes following cessation of the wind. These flats also receive some sand and mud brought into the area at time of storms; at other times, under normal bay-level conditions, wind-transported sand derived from barriers accumulates here. These are areas of great variation in intensity of physical conditions: temperature fluctuation is extreme, and chemical properties of surface and interstitial water is quite variable.

B. *TIDAL CHANNELS*

1. *Main channel*
Main channels are the primary lines of communication between the Gulf and the bays. Tidal range along the Gulf of Mexico is low (1.5-2.0 feet), and tidal currents are of relatively low velocity. Strong, persistent winds either offshore or onshore sometimes increase flow through tidal channels. During flood tide, the highest velocity is attained on the seaward side of the channel; during ebb tide, on the bayward side. Direction of flow through channels reverses itself twice daily with the tides. Deposition occurs at the bayward and seaward ends of channels by vertical accretion and along the channel banks. On the Texas Coast, lateral accretion is along the east bank. Holes are scoured in the channel at points of current convergence on the Gulf side and the bay side during flood and ebb tides, respectively.

2. *Flood delta*
Flood deltas, on the bay side of tidal channels, are constructed of sediment largely derived offshore. Jet flow develops at the distal end of the main channel; here, as the flow spreads radially, distributary channels form, and sediment accumulates as sand and mud shoals. Shoals may become emergent, creating new land, with the subaerial part of the delta developing into marshes, beach ridges, etc., that are affected by the same processes that act on similar features on the barriers. This type of land creation is especially significant at the mouth of the Brazos River.

3. *Ebb delta*
Sediment from which the ebb delta is constructed is also derived offshore. The process of deposition is the same as on the flood delta - by a decrease in velocity as the jet moves downcurrent from the channel mouth. Higher physical energy (wind-generated currents, primarily) in the Gulf waters than in the bays redistributes much of the ebb-delta sediment and prevents emergence of these features.

C. *BAYS AND LAGOONS*

1. *Bay perimeter* - areas not permanently inundated. Marsh, beach, and tidal-flat environments comprise the bay area above sea level. Processes on marshes and beaches are generally the same everywhere; however, beaches along bay margins are less well developed than those on the seaward side of barriers because of a lower physical-energy expenditure along bay margins.

Beaches within bays are not affected by astronomical tides; beach construction is by wind-generated waves. Material from which beaches are constructed consists of shell derived from barriers along the seaward-bay margin and of either river-borne sand or sand derived locally by undercutting of the Pleistocene.

2. *Shoal, marginal deposits*
In the larger bays, sand shoals occur along both the mainland and barrier shoreline. Sand source is fluvial (along mainland shore), from Pleistocene barrier islands, and from the back side of modern barriers. Distribution is by longshore drift; breaker bars are associated with unvegetated sandflats, particularly in either areas that front the prevailing southeast winds or areas that face into the tract of polar-air masses. Processes here are analogous to those operating on the upper shoreface of barrier islands; however, physical energy is less intense and biological activity relatively greater than along the barrier shoreface. Where bottom drift of sand is less vigorous, marine grasses become established; these plants retard the movement of the traction load and provide an energy baffle that allows deposition of suspension load (muds).

3. *Mud-settling basin*
Suspension-load material is derived from rivers, from the Gulf, and from undercutting of Pleistocene deposits along the mainland shore. Mud is supplied to bays from the Gulf through storm channels and tidal channels during storm-surge flood. Mud is the dominant sediment in most bays where water depth is 6 feet or more. Under normal bay conditions, transport of sand along the bay floor occurs in water less than 6 feet deep.

4. *Oyster reef*
Sedimentation within bays is affected by the larger, laterally extensive oyster reefs. Reefs cause an increase in current velocity by decreasing water depth immediately upcurrent and across the reef crest. As flow passes beyond the reef crest, velocity again decreases and pseudo-feces and suspension sediment are deposited. Oysters themselves build up the bay floor by shell accumulation.

D. *BAYHEAD AND ESTUARINE DELTAS*

These depositional features are the product of the interplay between fluvial and marine processes. Traction and suspension load travel together through the fluvial system to the mouth of distributaries. Beyond the mouth, traction and suspension load are segregated; traction load (sand) is dropped near the distributary mouth as current velocity

decreases abruptly. Suspension load (mud) is carried out into the bay, where it accumulates as prodelta muds. Most bayhead deltas front the prevailing onshore wind, which drifts fine sediment into interdistributary and marsh areas. Coarser material, sand, from the delta front is spread laterally and onshore by wind-generated waves to form relatively widespread sand sheets and beaches. Delta surfaces are built up from fine grained sediment (predominantly silt and mud) transported to the area through crevasse splays, from overbanking from distributaries, and from mud brought in from bays and deposited by wind tides. Much of the traction load accumulates in distributaries at about the point where the fluvial system begins to become shallow and to break up into numerous channels. Marshes, lakes, and swamps are integral parts of deltas; these receive mostly fine sediment from suspension. Water in the lakes and marshes ranges from fresh to normally saline.

E. *MARSHES*

Areas permanently inundated by a few inches of water or frequently flooded by astronomical tides are the habitat of salt-tolerant plants. Marshes occur on barriers and along mainland shorelines. Vegetation of these coastal marshes displays zonation with elevation, and the salt marshes are divided into low and high marsh. The low marsh is dominated by Spartina alterniflora, which grows in a few to several inches of water and can be seen forming a narrow vegetated band along the bays and tidal creeks. Where marginal areas are very shallow, Spartina alterniflora forms extensive marshlands. Landward, the low marsh grades into succulent plants (e.g., Batis, Salicornia, and Suaeda) and finally into Borrichia and Spartina spartinae.

Physical processes range from the minimal to the intense. Marsh sediment is disturbed by plant roots and burrowing animals (crustaceans and worms). Sediment deposited in marsh areas is transported into the area by a veriety of processes and is derived from several sources. On mainland sides of bays, sediment deposited in marshes is fluvially derived and is deposited by means of crevasse splays, overbanking, and wind tides. Sediments of marshes associated with barriers are deposited by wind tides, eolian processes, and hurricane washovers. Coastal marshes are areas of intense biological activity and extremes in physical processes. Fluctuations exist in temperature, in aridity, and in soil salinity. Because of their vegetation, marshes are very resistant to erosion, even when subjected to storm-generated currents and breaking waves.

F. *FLUVIAL SYSTEMS*

Most fluvial systems along the Texas Coastal Plain are of the fine-grained meander-belt type, e.g., Trinity, Brazos, and Nueces. The Colorado is a coarse-grained meander-belt type, and the San Bernard is locally braided. These stream types result from their particular types of discharge. Braided streams have very short-duration peak discharge, and fine-grained meander-belt streams have relatively long-duration peak discharge.

Most of the coarser grained sediment of meandering streams is deposited as lateral accretionary features - point bars - adjacent to the convex bank. Levees are constructed of both traction- and suspension-load material that is deposited along the channel banks at times when the stream overflows the channel; relatively coarse material is carried beyond the levee when crevasses are scoured through them. These deposits are the fan-shaped "crevasse splays." Beyond the levees, suspension load accumulates in the flood basin; flood waters move very sluggishly and finally stagnate. The flood plain is underlain by point-bar, levee, and flood-basin deposits. The flood plain is characterized by abandoned channel segments and meander cut-offs that are later filled with overbank sediment. These inactive channel segments show varying degrees of sediment fill and occur as linear or oxbow lakes, swamps, marshes, or depressions filled with mud. Swamps and marshes are best developed on flood plains near channel mouths.

G. *FOLIAN SYSTEMS*

Sand transport is generally toward the northwest under the driving force of the prevailing southeast winds. Dunes commonly develop downwind from devegetated older dunes. Blowouts result from devegetation of older dunes; this vegetation is killed or physically removed by over-grazing, fires, or storms. In this area, the wind is able to remove sand down to the water table. This sand moves downwind from the blowouts as parabolic or sief dunes. Sief dunes have crests modified by northers, but these north winds are not of sufficient duration to alter dune shape significantly or to transport a large volume of sand to the southeast. Dunes are ultimately stabilized by a vegetal cover of grass, mesquite, chaparral, some cacti, and, in some instances, live oaks.

Conditions which favor construction of an eolian plain such as that in South Texas are (1) a local sand source and (2) arid to semiarid climate. Sand here is derived from underlying abandoned deltaic-plain and meander belts. Winds blow from the southeast 9 months each year; average annual rainfall is generally fewer than 20 inches.

IV. EFFECTS OF MAN'S ACTIVITY ON COASTAL ENVIRONMENTS

The numerous uses of Coastal Zone lands and waters by man result in some use patterns *essentially in harmony with natural processes* and in others that *severely jeopardize the natural balance*: certain uses are in *sharp conflict with other uses*, especially within the Coastal Zone bays. Proper land and water uses will come only from a greater understanding of the natural processes at work in the area and of their relation to man's activity.

The purpose of this section is to outline some of man's activity and its relation to the natural environments and processes of the Coastal Zone.

CHANNELIZATION AND DREDGING - To date, the Coastal Zone bays have been the site of extensive dredging and channelization, involving the construction of *transportation canals*, *access canals* for specific bay operations, and *shell dredging*. All these activities are deemed a necessary part of the existing Coastal Zone industries, yet they affect the natural bay system significantly. Spoil dredged from canals and piled along the margins of the canals tends to compartmentalize the shallow bays and restrict circulation. *Reworking of dredged spoil* by waves and currents provides the principal supply of sediment to the bays. In many areas, *marginal grass flats - vital components in the bay ecosystem - are being blanketed by reworked spoil*, converting grass flats to barren sand areas.

Another type of channelization, construction of *artificial passes* between bays and the Gulf, affects the natural bay systems. Every pass cut through the barrier islands decreases the tidal surge through the existing passes. Most of the bays of the Texas Coastal Zone can naturally maintain only one pass per bay; artificial channels have to be maintained by continual dredging. In addition, passes, whether natural or artificial, receive the main tidal surges during storms. Additional passes make the barriers and the protected bay *more vulnerable to storm destruction.*

DEVEGETATION - The *importance of vegetation in land stabilization* is obvious when considering the changes in natural landforms along the present Texas Coast. The upper Coastal Zone is in a humid climate with mostly vegetated landforms; the southern part of the Coastal Zone is subtropical, with relatively low rainfall and fewer vegetated landforms. This dryness in large measure accounts for the extensive inland dune fields and the active dunes on the barrier islands of South Texas, as well as the extensive wind-tidal flats of Laguna Madre. The devegetation of natural landforms, whether a consequence of development, overgrazing, waste disposal, or marsh burning, *exposes bare sediment to erosion* by storm and by normal waves and currents and significantly reduces the stability of the land. Vegetated barrier islands afford the

best natural protection from hurricanes and storms. Devegetation in *landside-drainage* systems greatly increases the sediment load of streams, resulting in increased infilling of the bays into which the streams discharge. For example, the natural and artificial drainage system of Gum Hollow, a small stream emptying into Nueces Bay, delivered *270,000 cubic yards* of sediment into the bay during the heavy rainfall accompanying Hurricane Beulah. This resulted chiefly because stabilizing vegetation in the stream was killed by brine discharge from petroleum production operations.

LAND RECLAMATION - Artificial filling of bays and marshlands provides valuable *shorefront development land* or room for industrial expansion, *but it also provides sediment* for hurricane erosion and redistribution, *impedes effective bay circulation,* and locally *reduces bay area,* causing additional flooding elsewhere during high water.

COASTAL CONSTRUCTION - Construction of numerous groins, piers, jetties, and platforms has modified circulation patterns within many bays and estuaries. Erosion and deposition within the natural system is *upset,* and entire baylines may become *unbalanced,* resulting in *choking deposition* in some areas and *damaging erosion* in other shoreline stretches. Necessary coastal construction should be *planned to minimize alteration of natural circulation,* thus preventing unmanaged shoreline changes.

Several factors should be considered when planning coastal structures designed to *prevent destruction of property by hurricanes.* Barrier islands are *natural barriers* to much of the surge effect of storms. Some of the storm's energy passes through natural passes in the barriers to flush bays and naturally dredge tidal channels. Because some hurricanes are of such great magnitude, breaching in the form of washover channels permits additional amounts of the storm surge to reach bays. Isolating back-bay areas by man-made structures may *adversely affect flushing* of these water bodies, a very critical process, since man has already restricted the volume of streams entering the bays by construction of upstream dams. Reduction of natural flushing processes would *increase and emphasize the effects of pollution of the bay waters.*

WASTE DISPOSAL - Most of the problems of waste disposal associated with large industrial and metropolitan areas have been well publicized. *An area usually not emphasized is the disposal of waste through subsurface media.* Areas of permeable substrates should be avoided as sites of disposal, since these permeable materials directly connect with the ground-water system. Construction of septic tanks in loose and permeable spoil should also be avoided. Abandoned sand pits may make readily available sites for waste disposal from an immediate economic point of view, but they are the worst possible sites form the standpoint of protecting ground-water supplies. Extensive areas of the Coastal Zone are underlain by tight impermeable clays which are ideal waste-disposal sites. Unfortunately, these clays support the more fertile soils of the coastal area.

MINERAL EXTRACTION - The bays and estuaries of the Texas Coastal Zone are the sites of numerous *oil and gas fields;* they are also sites for the *dredging of shell.* Both of these operations are potential sources of pollution if production operations are not carefully managed.

TABLE I

	ARANSAS	BRAZORIA	CALHOUN	CAMERON	CHAMBERS	GALVESTON
USE						
Total Area[1]	464.0	1520.0	960.0	1200.0	896.0	696.0
Total Land Area[2]	281.0 - *61.0*	1443.0 - *95.0*	536.0 - *56.0*	1082.0 - *90.0*	625.0 - *70.0*	431.0 - *62.0*
Total H_2O Area[2]	183.0 - *39.0*	77.0 - *5.0*	424.0 - *44.0*	118.0 - *10.0*	271.0 - *30.0*	265.0 - *38.0*
LAND AREAS						
Agriculture[3]	21.0 - *7.5*	620.0 - *43.0*	117.0 - *21.8*	704.0 - *65.1*	345.0 - *55.2*	246.0 - *57.1*
Range-Ranch[3]	132.0 - *47.0*	84.0 - *5.8*	262.0 - *48.9*	132.0 - *12.2*	51.0 - *8.2*	40.0 - *9.3*
Woodland-Timber[3]	--- ---	502.0 - *34.8*	42.0 - *7.8*	--- ---	70.0 - *11.2*	16.0 - *3.7*
Marsh-Swamp[3]	22.0 - *7.8*	56.0 - *3.9*	75.0 - *14.0*	0.1 - *0.0*	101.0 - *16.2*	55.0 - *12.8*
Urban Industrial-Residential[3]	10.0 - *3.6*	128.0 - *8.9*	18.0 - *3.4*	7.1 - *6.6*	37.0 - *5.9*	58.0 - *13.5*
Recreational[3]	1.2 - *0.4*	1.8 - *0.1*	2.3 - *0.4*	1.7 - *0.2*	.0.1 - *0.0*	3.2 - *0.7*
Subaerial Spoil[3]	1.6 - *0.6*	4.8 - *0.3*	8.0 - *1.5*	8.2 - *0.8*	2.5 - *0.4*	8.3 - *1.9*
Made Land[3]	--- ---	3.2 - *0.2*	--- ---	--- ---	--- ---	3.9 - *0.9*
Wildlife Refuge[3]	77.0 - *27.4*	43.0 - *3.0*	4.0 - *0.7*	69.0 - *6.4*	18.0 - *2.9*	--- ---
Barren Land[3]	16.0 - *5.6*	--- ---	8.0 - *1.5*	96.0 - *8.9*	--- ---	1.0 - *0.2*
WATER AREAS						
Bays[2]	179.0 - *38.6*	42.0 - *2.8*	404.8 - *42.2*	92.0 - *7.7*	243.0 - *27.1*	257.0 - *36.9*
Artificial Reservoirs[1]	---	16.0	---	10.0	4.4	1.2
Natural Fresh Water Bodies[1]	4.2	19.2	18.9	16.0	24.0	6.4
OTHER FEATURES						
Bay Shoreline[4]	140.0	54.0	286.0	96.0	63.0	120.0
Open Ocean Shoreline[4]	20.0	30.0	38.0	32.0	1.0	50.0
Total Shoreline[4]	160.0	84.0	324.0	128.0	64.0	170.0
Drainage Channels[4]	3.0	372.0	100.0	≈730.0	280.0	85.0
Transportation Canals[4]	29.0	68.0	52.0	32.0	44.0	76.0
Hurricane Flood Areas[2]	135.0 - *48.4*	422.0 - *29.2*	371.0 - *69.2*	120.0 - *11.1*	283.0 - *45.3*	257.0 - *59.6*

[1]measured in square miles

[2]measured in both square miles (gothic print) and % of total area (italics)

[3]measured in both square miles (gothic print) and % of total land area (italics)

[4]measured in linear miles

T A B L E I (Continued)

USE	HARRIS	JACKSON	JEFFERSON	KENEDY	KLEBERG	MATAGORDA
Total Area[1]	544.0	576.0	1024.0	1824.0	960.0	1408.0
Total Land Area[2]	522.0 - *96.0*	572.0 - *99.0*	946.0 - *92.0*	1757.0 - *96.0*	812.0 - *85.0*	1157.0 - *82.0*
Total H_2O Area[2]	22.0 - *4.0*	4.0 - *1.0*	78.0 - *8.0*	67.0 - *4.0*	148.0 - *15.0*	251.0 - *18.0*
LAND AREAS						
Agriculture[3]	285.0 - *54.6*	250.0 - *43.7*	442.0 - *46.7*	--- ---	32.0 - *3.9*	593.0 - *51.3*
Range-Ranch[3]	--- ---	257.0 - *44.9*	24.0 - *2.5*	1186.0 - *67.5*	704.0 - *86.7*	180.0 - *15.6*
Woodland-Timber[3]	56.0 - *10.7*	42.0 - *7.3*	81.0 - *8.6*	245.0 - *13.9*	24.0 - *3.0*	245.0 - *21.1*
Marsh-Swamp[3]	16.0 - *3.1*	13.0 - *2.3*	220.0 - *23.3*	--- ---	2.4 - *0.3*	87.0 - *7.5*
Urban Industrial-Residential[3]	160.0 - *30.6*	10.0 - *1.7*	168.0 - *17.8*	0.5 - *0.0*	12.0 - *1.5*	37.0 - *3.2*
Recreational[3]	--- ---	--- ---	2.0 - *0.2*	3.3 - *0.2*	1.4 - *0.2*	3.6 - *0.3*
Subaerial Spoil[3]	4.8 - *0.9*	--- ---	1.3 - *0.1*	18.0 - *1.0*	4.8 - *0.6*	11.0 - *1.0*
Made Land[3]	--- ---	--- ---	6.1 - *0.6*	--- ---	--- ---	--- ---
Wildlife Refuge[3]	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
Barren Land[3]	--- ---	--- ---	1.6 - *0.2*	304.0 - *17.3*	31.0 - *3.8*	0.8 - *0.1*
WATER AREAS						
Bays[2]	15.2 - *2.8*	--- ---	32.0 - *3.1*	64.0 - *3.5*	128.0 - *13.3*	242.2 - *17.2*
Artificial Reservoirs[1]	3.0	---	24.0	---	---	---
Natural Fresh Water Bodies[1]	4.0	4.0	22.0	3.2	20.4	8.4
OTHER FEATURES						
Bay Shoreline[4]	40.0	---	17.0	126.0	144.0	129.0
Open Ocean Shoreline[4]	---	---	33.5	50.0	23.0	62.0
Total Shoreline[4]	40.0	---	50.5	176.0	167.0	191.0
Drainage Channels[4]	115.0	154.0	320.0	---	1.0	340.0
Transportation Canals[4]	26.0	---	80.0	54.0	23.0	58.0
Hurricane Flood Areas[2]	54.0 - *10.3*	78.0 - *13.6*	468.0 - *49.5*	160.0 - *9.1*	90.0 - *11.1*	464.0 - *40.1*

[1]measured in square miles

[2]measured in both square miles (gothic print) and % of total area (italics)

[3]measured in both square miles (gothic print) and % of total land area (italics)

[4]measured in linear miles

T A B L E I (Continued)

USE	NUECES	ORANGE	REFUGIO	SAN PATRICIO	VICTORIA	WILLACY
Total Area[1]	1024.0	392.0	832.0	600.0	440.0	768.0
Total Land Area[2]	739.0 - *72.0*	378.0 - *96.0*	792.0 - *95.0*	590.0 - *98.0*	438.0 - *100.0*	717.0 - *93.0*
Total H_2O Area[2]	285.0 - *28.0*	14.0 - *4.0*	40.0 - *5.0*	10.0 - *2.0*	2.0 - *0.0*	51.0 - *7.0*
LAND AREAS						
Agriculture[3]	450.0 - *60.9*	77.0 - *20.4*	117.0 - *14.8*	363.0 - *61.5*	119.0 - *27.1*	336.0 - *46.9*
Range-Ranch[3]	86.0 - *11.6*	--- ---	640.0 - *80.8*	166.0 - *28.1*	240.0 - *54.8*	241.0 - *33.6*
Woodland-Timber[3]	22.0 - *3.0*	159.0 - *42.1*	11.2 - *1.4*	12.8 - *2.2*	73.0 - *16.7*	8.0 - *1.1*
Marsh-Swamp[3]	14.4 - *1.9*	71.0 - *18.8*	68.0 - *0.9*	19.0 - *3.2*	3.2 - *0.7*	0.8 - *0.1*
Urban Industrial-Residential[3]	138.0 - *18.7*	69.0 - *18.3*	15.0 - *1.9*	28.0 - *4.7*	3.2 - *0.7*	7.0 - *1.0*
Recreational[3]	1.9 - *0.3*	--- ---	--- ---	--- ---	--- ---	0.8 - *0.1*
Subaerial Spoil[3]	8.0 - *1.1*	16.0 - *0.4*	--- ---	--- ---	--- ---	1.8 - *0.3*
Made Land[3]	19.0 - *2.6*	--- ---	--- ---	1.6 - *0.3*	--- ---	--- ---
Wildlife Refuge[3]	--- ---	--- ---	1.6 - *0.2*	--- ---	--- ---	0.8 - *0.1*
Barren Land[3]	--- ---	--- ---	--- ---	--- ---	--- ---	121.0 - *16.9*
WATER AREAS						
Bays[2]	282.0 - *27.5*	12.5 - *3.2*	33.6 - *4.0*	6.0 - *1.0*	--- ---	42.0 - *5.5*
Artificial Reservoirs[1]	1.3	1.9	---	1.5	1.0	0.4
Natural Fresh Water Bodies[1]	1.4	---	6.8	2.1	0.6	8.4
OTHER FEATURES						
Bay Shoreline[4]	80.0	9.3	32.0	47.0	---	36.0
Open Ocean Shoreline[4]	21.0	---	---	---	---	12.6
Total Shoreline[4]	101.0	9.3	32.0	47.0	---	48.6
Drainage Channels[4]	133.0	154.0	70.0	83.0	80.0	100.0
Transportation Canals[4]	72.0	39.0	---	---	---	15.0
Hurricane Flood Areas[2]	88.0 - *11.9*	94.0 - *24.8*	42.0 - *5.3*	40.0 - *6.7*	24.0 - *5.4*	18.0 - *2.5*

[1]measured in square miles

[2]measured in both square miles (gothic print) and % of total area (italics)

[3]measured in both square miles (gothic print) and % of total land area (italics)

[4]measured in linear miles

T A B L E I (Continued)

USE	TOTALS
Total Area[1]	16128.0
Total Land Area[2]	13818.0 - *86.0*
Total H_2O Area[2]	2310.0 - *14.0*
LAND AREAS	
Agriculture[3]	5117.0 - *37.0*
Range-Ranch[3]	4425.0 - *32.0*
Woodland-Timber[3]	1609.0 - *11.6*
Marsh-Swamp[3]	762.7 - *5.5*
Urban Industrial-Residential[3]	969.7 - *7.0*
Recreational[3]	23.3 - *0.2*
Subaerial Spoil[3]	84.7 - *0.6*
Made Land[3]	33.8 - *0.2*
Wildlife Refuge[3]	213.4 - *1.5*
Barren Land[3]	579.4 - *4.2*
WATER AREAS	
Bays[2]	2075.3 - *12.9*
Artificial Reservoirs[1]	
Natural Fresh Water Bodies[1]	
OTHER FEATURES	
Bay Shoreline[4]	
Open Ocean Shoreline[4]	
Total Shoreline[4]	
Drainage Channels[4]	
Transportation Canals[4]	
Hurricane Flood Areas[2]	3208.0 - *23.3*

[1]measured in square miles

[2]measured in both square miles (gothic print) and % of total area (italics)

[3]measured in both square miles (gothic print) and % of total land area (italics)

[4]measured in linear miles

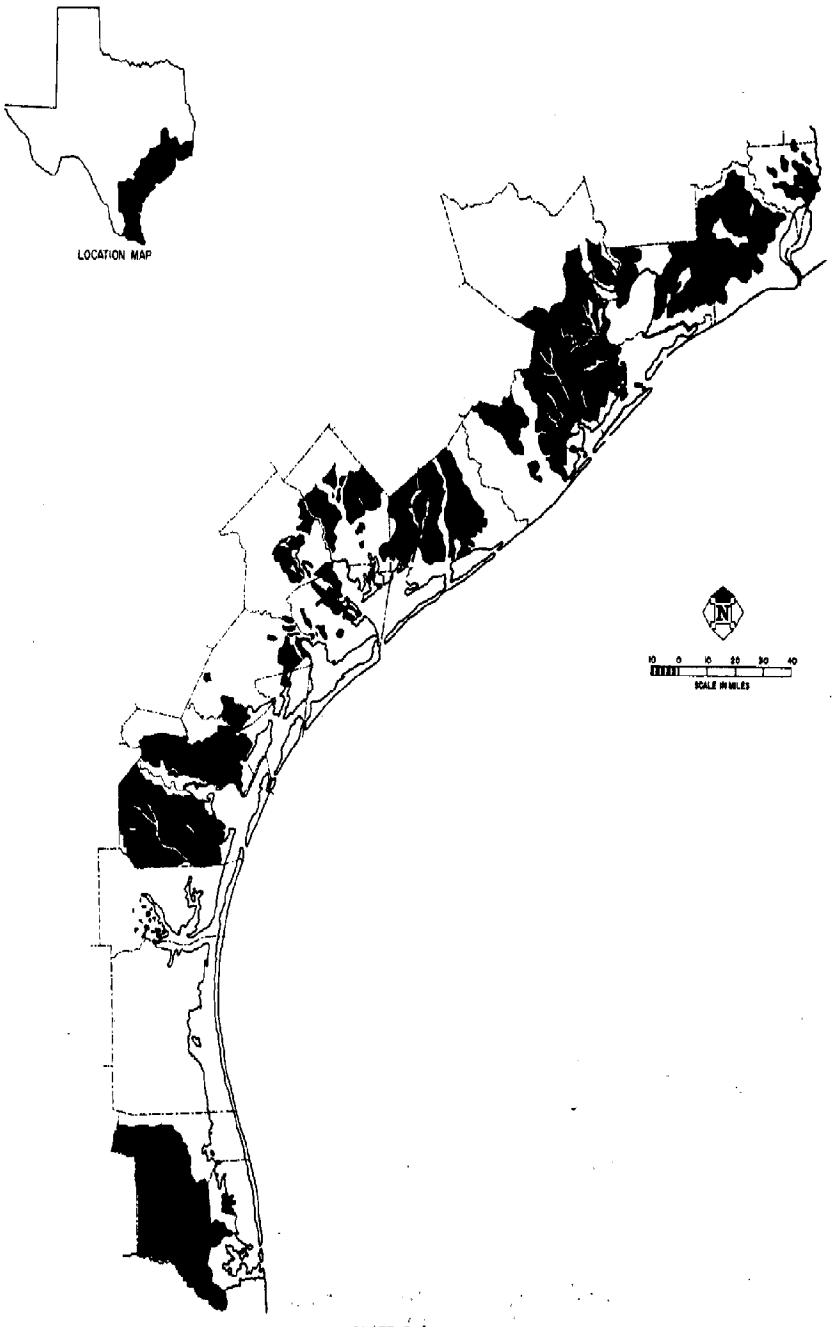

PLATE I-A.

AGRICULTURE: CULTIVATED LANDS

IN THE COASTAL ZONE

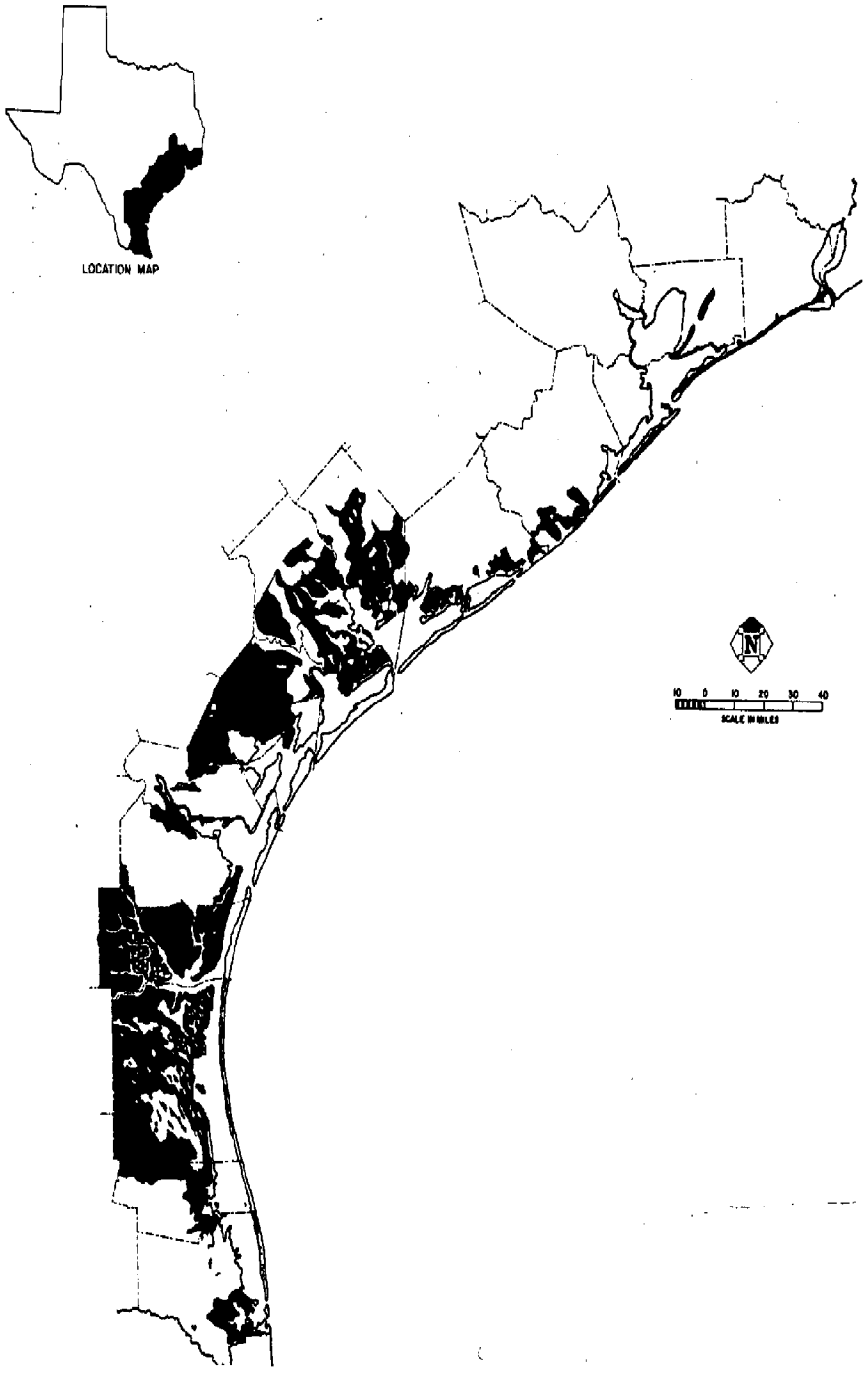

PLATE I-B.

RANGE - RANCHLAND IN THE COASTAL ZONE

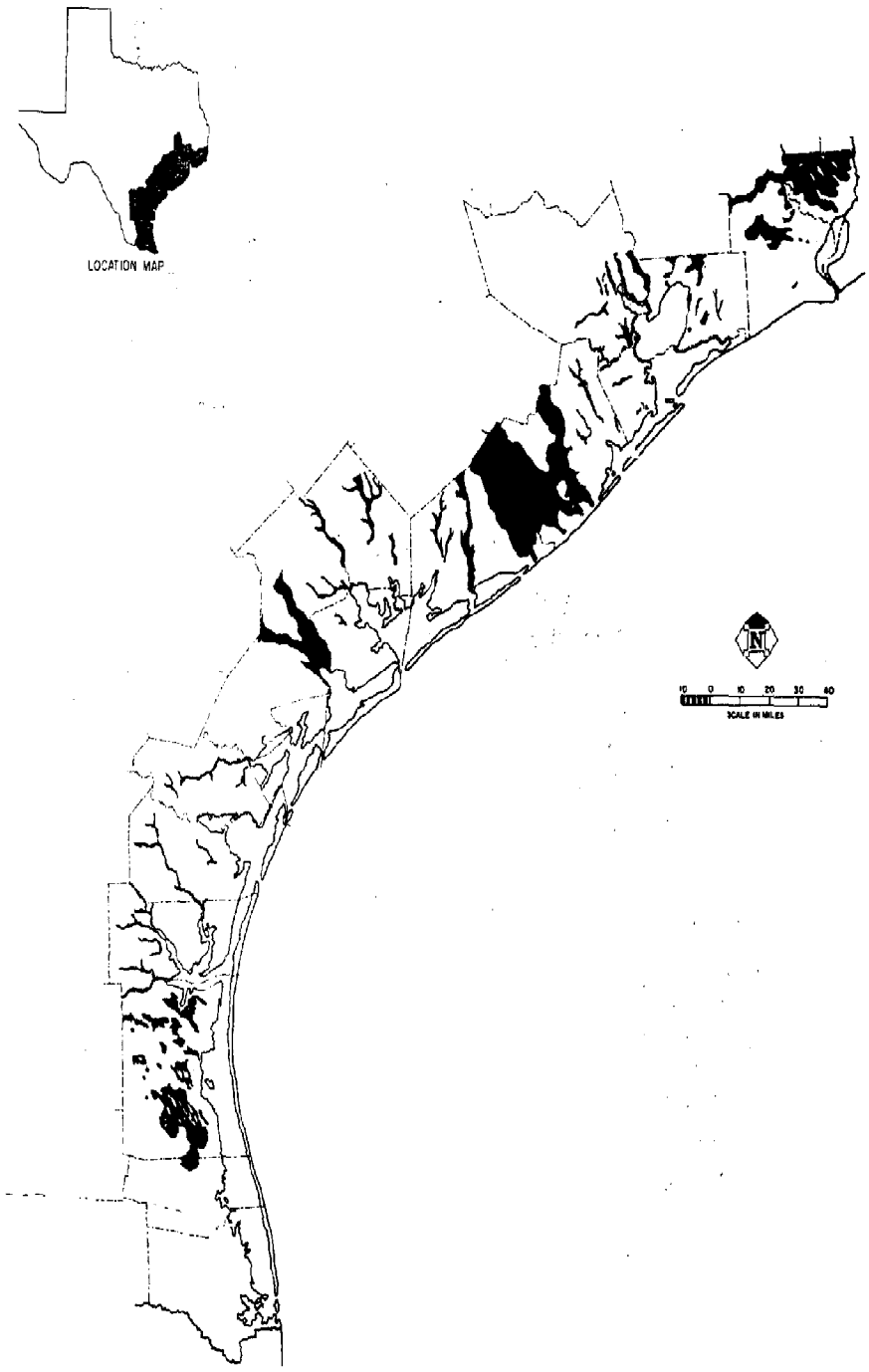

PLATE I-C.

TIMBER - WOODLANDS IN THE COASTAL ZONE

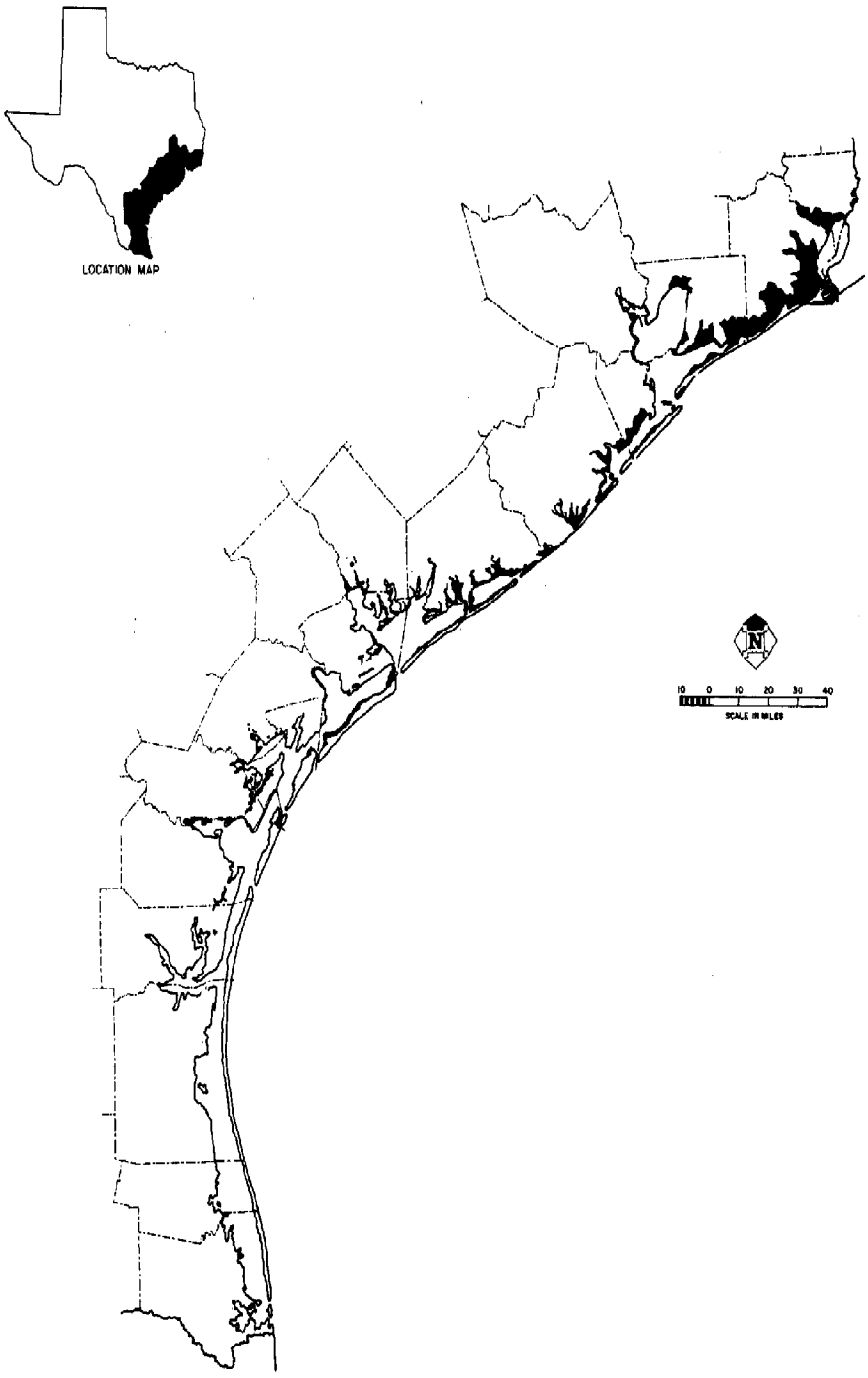

PLATE I-D.

MARSHLANDS IN THE COASTAL ZONE

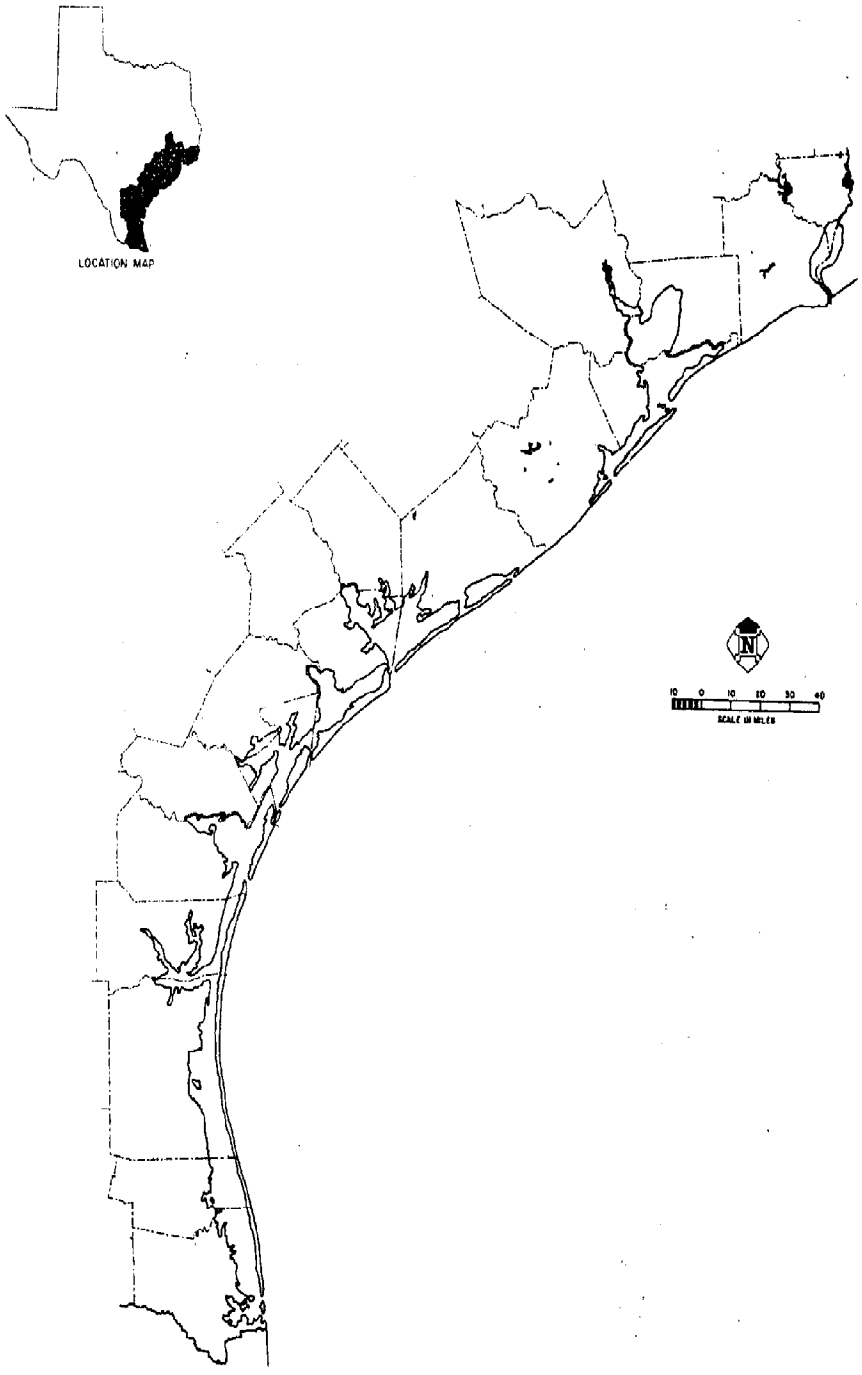

PLATE I-E.

SWAMPLANDS IN THE COASTAL ZONE

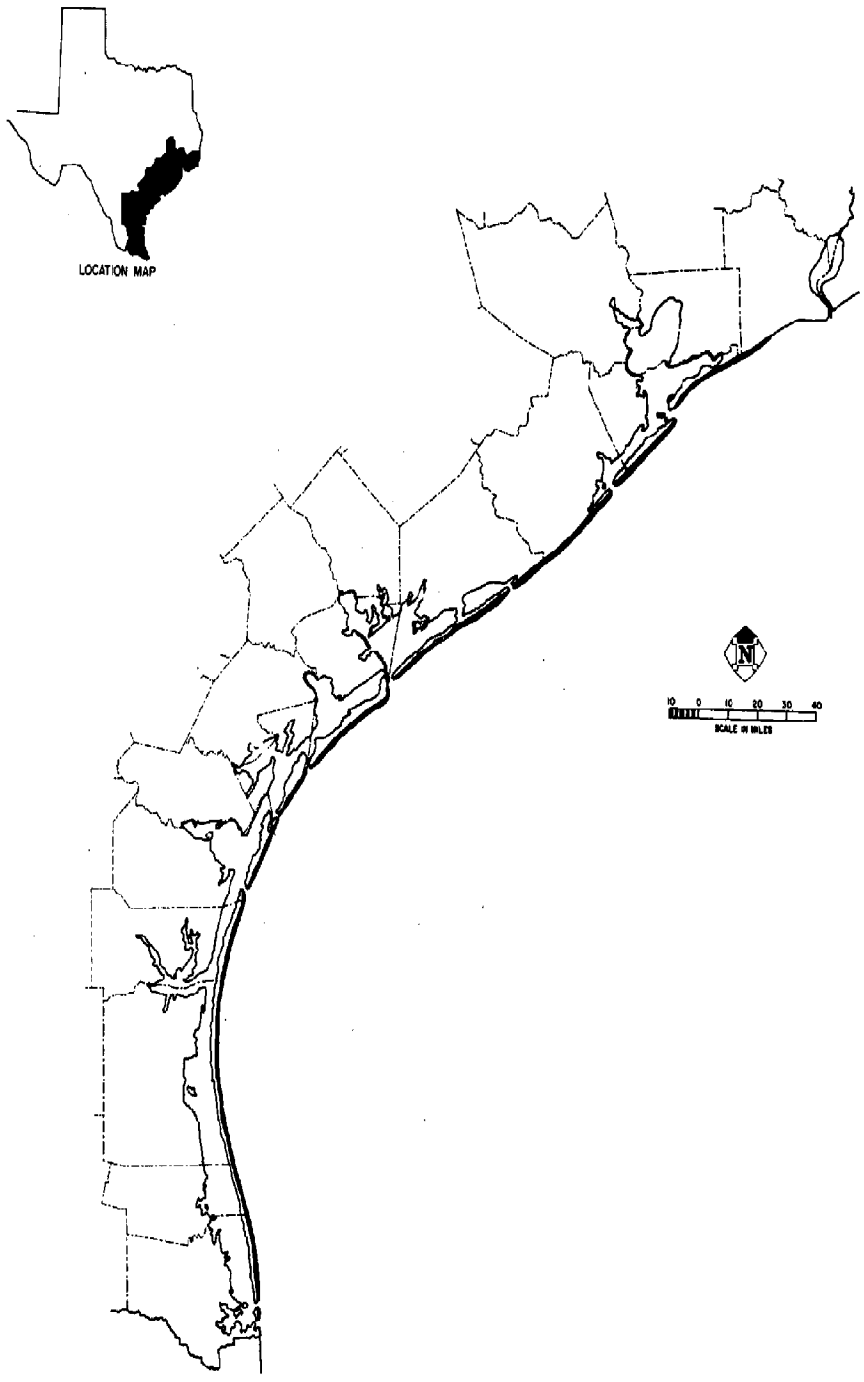

PLATE I-F.

RECREATIONAL BEACHES IN THE COASTAL ZONE

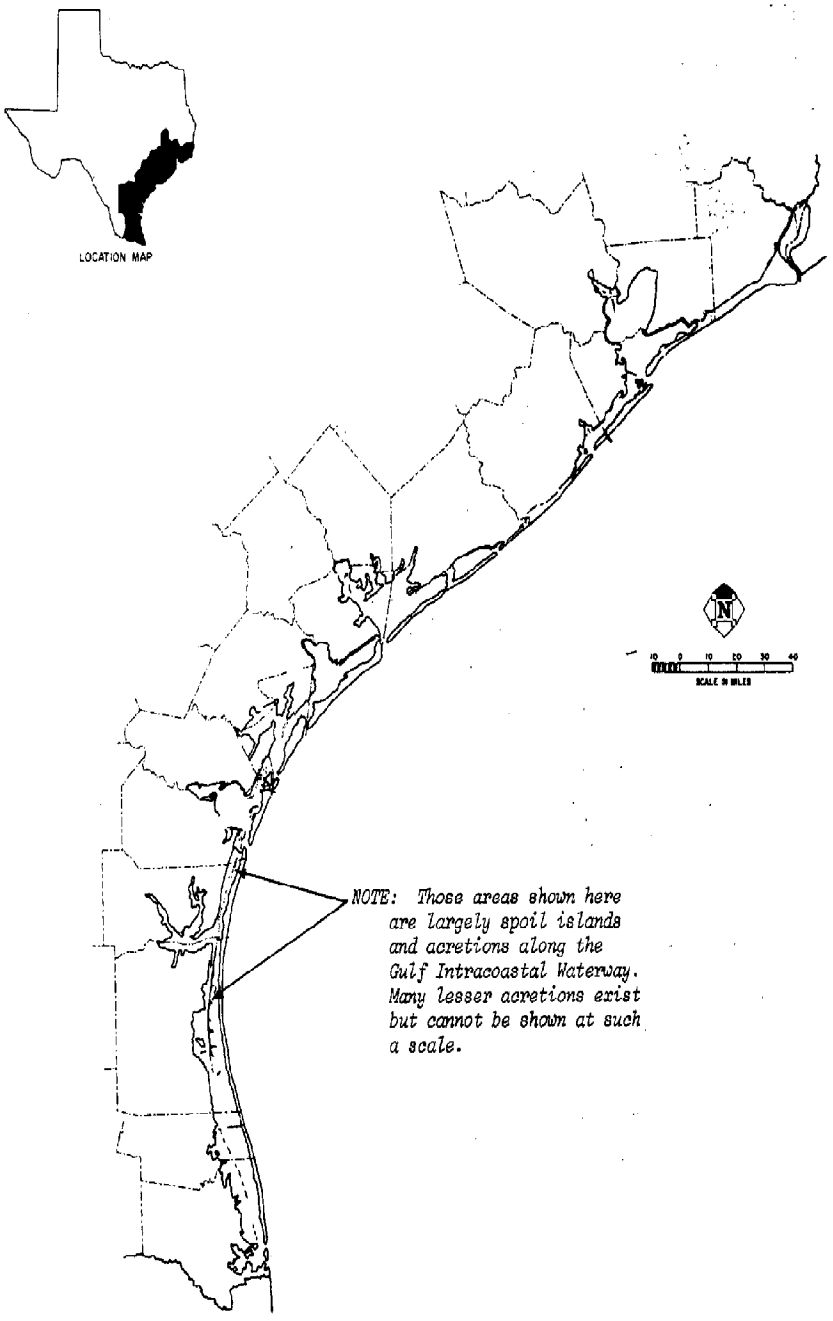

PLATE I-6.

SPOIL ISLANDS AND OTHER BUILT-UP LANDS

IN THE COASTAL ZONE

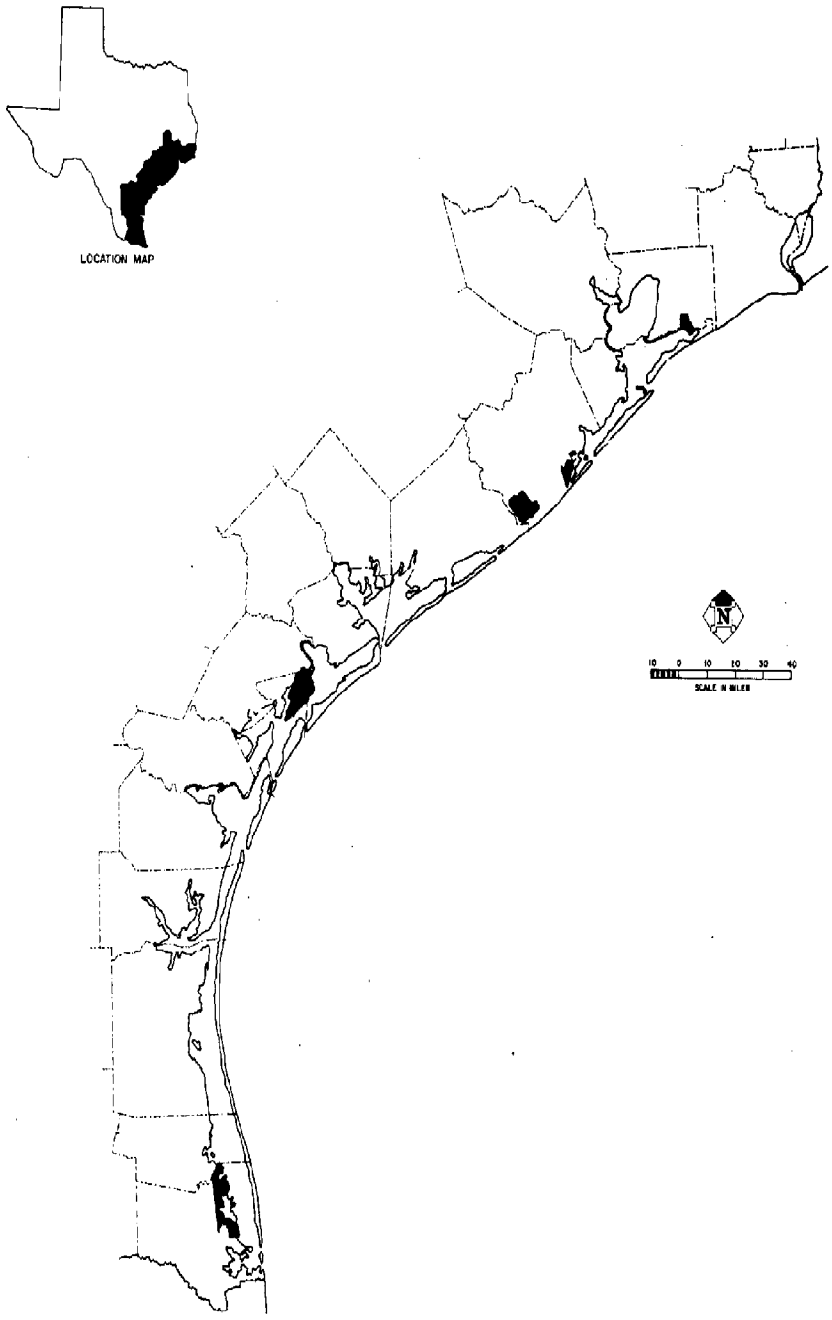

PLATE I-H.

FORMAL WILDLIFE REFUGES IN THE

COASTAL ZONE

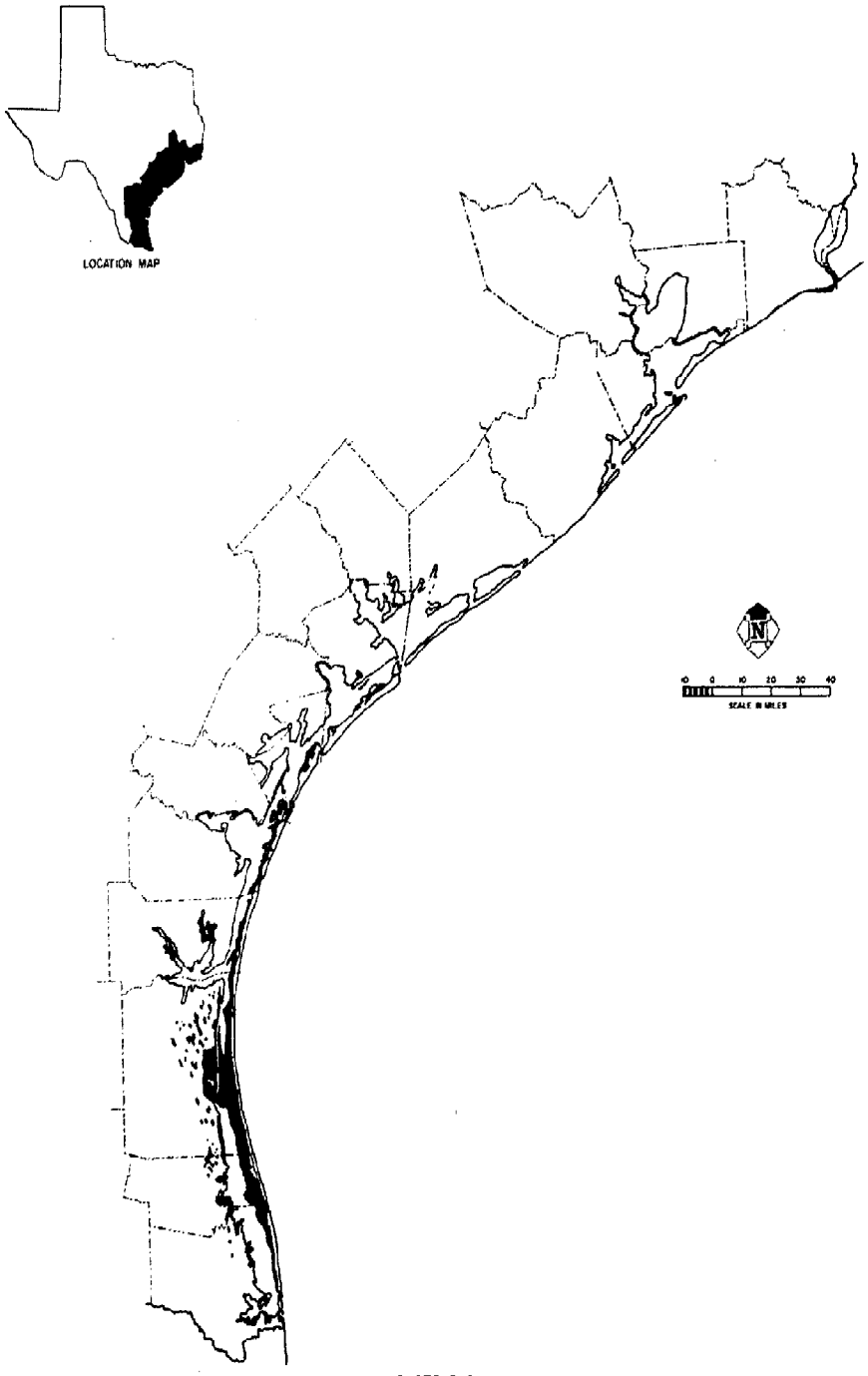

PLATE I-I.

BARREN LANDS IN THE COASTAL ZONE

ATTACHMENT A

Purpose

The Environmental Geologic Atlas is designed to provide critical information for planning and land use in the populous and industrial coastal zone of Texas and for a better understanding of physical, biological, and chemical environments of the coastal zone in order to assess and judge properly the status of these resources.

Approach

Detailed mapping and study in the field and by light aircraft; geologic environments, sediments, landforms were mapped on 1:24,000-scale aerial photographs. Approximately 20,000 square miles of coastal zone from shoreface to about 50 miles inland (see index).

Status

Four geologists and several technicians and cartographers have worked for 18 months on the project. All mapping is now complete and the maps and report are in preparation for publication.

Contents

The Environmental Geologic Atlas of the Texas Coastal Zone will consist of a folio of 63 geologic and multi-colored environmental maps accompanied by text explaining use and interpretation. The coastal zone was divided into seven map areas: Brownsville-Harlingen, Kingsville, Corpus Christi, Port Lavaca, Bay City-Freeport, Galveston-Houston, and Beaumont-Port Arthur. For each of the areas, the following maps were prepared:

Environmental Geologic Maps: scale 1:125,000; total of 125 map units including landforms, sediments, bedrock, and certain plant communities; Bureau-constructed base map includes 5-foot contours, 3-foot bathymetric lines, paved roads, cities, pipelines, and other physical and cultural information. Emphasis has been on mapping basic units from which a variety of data can be derived.

Land-Use Maps: Inventory (25 map units) of present use including agriculture, range, woodland-timber, wildlife, spoil and made land, recreation, residential-urban, industrial, and sewage disposal.

Water Systems - Man-made Features: Inventory (15 map units) of made land, types of spoil land, jetties, piers, sea walls, rivers, lakes, sloughs, estuaries, reservoirs, canals and ditches, channels, and tidal inlets.

Engineering Properties: Distribution (15 map units) of properties such as water-holding capacity, compressibility, shrink-swell, drainage, relief, shear strength, plasticity, flooding, permeability, mineral content, faults, and other features.

Biologic-Assemblage Map: Approximately 45 subaerial plant and subaqueous animal communities.

Physical Processes Map: Hurricane surge and flood areas, shoreline erosion, equilibrium and deposition, circulation patterns, sediment dispersal, tidal data.

Salinity-Climatic Maps: Contoured salinity in bays and estuaries during droughts and rainy seasons, average salinity; graphs of salinity for each bay and estaury; rainfall data; water and sediment discharge for rivers entering coastal zone.

Mineral and Energy Resources Map: Approximately 15 units including source of sand and clay, oyster reefs, utility lines, pipelines, quarries, oil-gas fields, sulfur fields, salt domes, cement plants, power plants, brine wells and other data.

Depositional Systems Map: Display of active or ancient genetic units such as fluvial, deltaic, marsh, swamp, barrier-cheniers, bay-lagoon-estuary, eolian and off-shore systems.

Publication Date

The folio will be available during the first half of 1971.

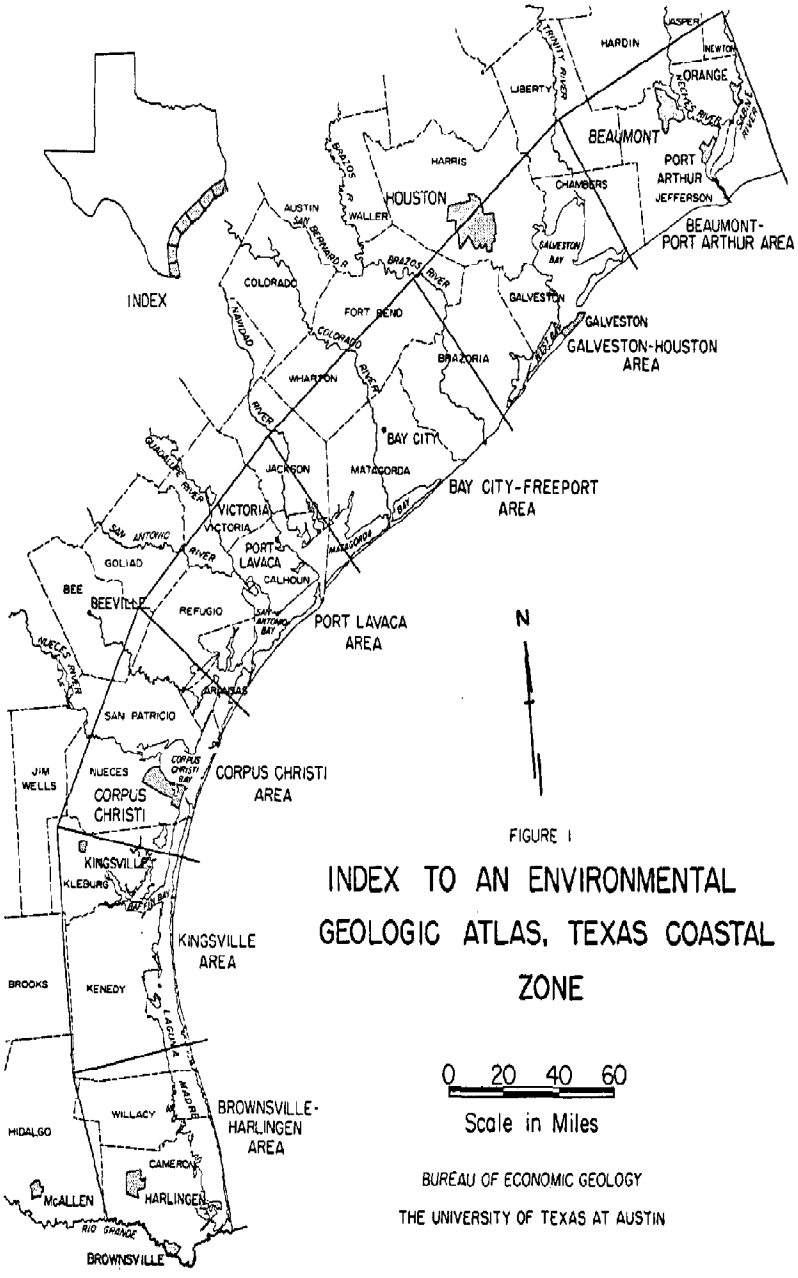

FIGURE 1

INDEX TO AN ENVIRONMENTAL GEOLOGIC ATLAS, TEXAS COASTAL ZONE

0 20 40 60

Scale in Miles

BUREAU OF ECONOMIC GEOLOGY

THE UNIVERSITY OF TEXAS AT AUSTIN